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# VARIETY STUDIES IN RELATION TO FUSARIUM WILT OF PEAS

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## INTRODUCTION

For many years considerable confusion existed in the minds of investigators as to the exact cause of the heavy losses to the pea crop (*Pisum sativum* L.) in certain parts of the United States. These losses were generally assumed to be caused by organisms living in the soil and belonging to what is popularly called the root rot complex. The behavior of some of the plants in certain sections of the country and under certain environmental conditions did not accord exactly with the recognized symptomatology of root rot. This variation from typical root rot symptoms in some of the diseased plants resulted in the initiation of investigations and the discovery by Linford (*6*)[1] that there was associated with the so-called root rot complex an organism, *Fusarium orthoceras* App. and Wr. var. *pisi* Linford, which invaded the vascular bundles of the root and stem and caused a typical wilt that bore close resemblance to the wilt disease of certain other crops such as tomatoes, cotton, and cucumbers. This discovery stimulated interest in the production of strains resistant to wilt, and investigators of some of the State experiment stations and geneticists of certain seed companies began testing different pea varieties to determine their susceptibility or resistance to the disease. These trials showed that some varieties were homozygous for resistance, some homozygous for susceptibility, and others were a mixture of biotypes. No heterozygous plants were found in the course of these investigations. The breeding program has re-

[1] Italic numbers in parentheses refer to Literature Cited, p. 25.

sulted in the production of a number of wilt-resistant strains, some even in the normally susceptible varieties.

Since the discovery of fusarium wilt of peas (*6*) and its cause, a number of contributions on different phases of the problem have been made. In 1928 Linford [2] found the disease to be present in Wisconsin, Michigan, Indiana, Maryland, Pennsylvania, Ohio, Illinois, Idaho, Montana, and possibly California. Its presence in California has recently been confirmed by Snyder.[3] In the field of genetics Wade (*13*) discovered that resistance of peas to fusarium wilt was due to a single dominant factor.

Recently Snyder (*10*) has shown that while strains of the pea wilt fungus (*Fusarium orthoceras* var. *pisi*) exist, they differ only in degree of virulence and not in fundamental pathogenicity. According to Kadow and Jones (*5*) and Snyder (*9*), the causal organism is seed borne to a very slight degree.

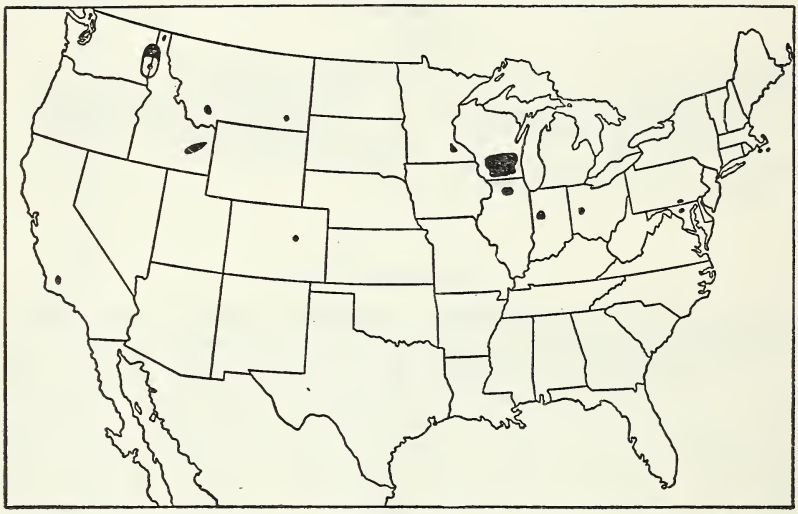

FIGURE 1.—Distribution of pea wilt, caused by *Fusarium orthoceras* var. *pisi*, in the United States.

Figure 1 shows the distribution of fusarium wilt of peas in the United States as it is now known. This parasite is apparently adaptable to a wide range of conditions in pea-growing areas from the Atlantic to the Pacific Oceans, and in a belt over 900 miles wide, from 49° north latitude at Bonners Ferry, Idaho, to 35° at San Luis Obispo, Calif. It is interesting to note that it has not been reported from the important pea-growing areas of New York, Florida, or the Imperial Valley in California. There is apparently not much effect from elevation as such, since the organism occurs near sea level in Maryland and California and at an elevation of 5,000 feet in Colorado. In Wisconsin and eastern Washington, where damage from wilt has been greatest, the elevations are approximately 800 and 2,200 feet, respectively.

[2] LINFORD, M. B. PEA DISEASES IN THE UNITED STATES IN 1928. U. S. Dept. Agr., Plant Disease Rept. Sup. 67, 14 pp. 1929.

[3] SNYDER, W. C. FUSARIUM WILT OF PEAS IN CALIFORNIA. U. S. Dept. Agr., Plant Disease Rept. 17 (4): 31. May 1, 1934.

The organism occurs in a very wide range of soils from the heavy loams of Wisconsin to the loess soils south of Spokane, Wash. It also thrives fairly well in the gravelly soils near San Luis Obispo, Calif., and in the silty clays of Maryland. The lighter soils of north-central Wisconsin and eastern Maryland do not seem to be particularly favorable for the organism. Walker (*14*) indicated that in some cases the organism appears to be more virulent in heavy soil, but possible effects of other organisms were not taken into consideration.

The purpose of this circular is to discuss (1) wilt reaction of varieties that are important or related to important varieties in the United States; (2) relation of climate to the prevalence of pea wilt; (3) diversity of pathogens and origin of pea varieties in relation to wilt; (4) relation of primitive types to resistance; and (5) possible origin and survival of genes determining resistance and susceptibility.

## METHODS AND MATERIALS

Beginning in 1931 and continuing through a period of several years 547 seed samples of pea (*Pisum sativum*), comprising a large number of varieties, were collected from all parts of the United States. To this number was added 477 samples assembled from many parts of the world by D. N. Shoemaker, making a total of 1,024. Little was known about the previous history of these different pea varieties and strains with reference to resistance to fusarium wilt. A field test was made at Fairfield, Wash., on soil known to be heavily infested with the wilt organism and where previous crops had been largely destroyed. The first planting was made in 1931 in duplicates, designated as series 1 and 2. In 1932 and 1933 additional tests were made, the purpose being to study susceptibility and resistance of varieties especially adapted for market-garden purposes. The number of lots and varieties planted in 1932 and 1933 was considerably less than in 1931.

In 1931 the checks of series 1, consisting of 10 seeds of a resistant and 10 seeds of a susceptible strain, were planted in every twenty-first plot across the field. In series 2 no resistant checks were used, but susceptible checks on both sides of the area wilted completely. In series 1, a few of the susceptible checks did not wilt completely, so the entire series is omitted from the compilations of varietal reactions (table 2). On the whole, however, the results of series 1 corroborated those obtained in series 2. Wilting of susceptible plants was complete in about 70 days after planting, but notes were taken at intervals throughout the entire season. Varietal reactions are based on an average of about 25 plants per strain.

Known susceptible varieties distributed throughout the second series of 1931 wilted completely and furnished the equivalent of a check series. Additional evidence of the completeness of elimination of susceptible plants in the second series was supplied by progenies the following year. Seed from several hundred survivors selected from series 2 were planted in 1932 on heavily infested soil with both resistant and susceptible checks at frequent intervals. The susceptible checks wilted completely, but none of the resistant selections nor any of the resistant checks showed any symptoms of wilt. Also four selections from one known susceptible variety showed symptoms of wilt.

In 1932 and 1933 the objective was to locate, if possible, desirable early market-garden strains showing resistance to fusarium wilt. Checks (10 seeds of a susceptible and 10 of a resistant variety) were planted in every eleventh plot. In addition, a row each of susceptible and resistant varieties was planted almost completely around the irregular, somewhat elongated area used during those 2 years. In no case was a plant from known susceptible strains alive 60 days after planting. Each strain was planted in duplicate and the total number of plants per progeny was well over 200 in 1932 and over 50 in 1933. The size of the plots was reduced in 1933, because results of the previous year indicated that large populations were not necessary to determine the reactions of a given strain or variety. The same area was used in both years. It was about 500 feet distant from the plot of 1931.

Isolations from plants in various parts of the field were made from time to time throughout the summer, and the results indicated that the wilting was caused only by *Fusarium orthoceras* var. *pisi*. There is no reason to believe that either the near-wilt described by Snyder and Walker (*11*) or the new wilt described by Harter (*3*) as due to *F. oxysporum* Schl. var. *aurantiacum* (Lk.) Wr. and that caused by *F. vasinfectum* Atk. var. *lutulatum* (Sherb.) Wr. were present to obscure the results.

Heavily wilt-infested soils from two different sources were placed in the greenhouse at Arlington Experiment Farm, Arlington, Va., where further tests could be made of any pea strains about which the result was in doubt, and where certain additional and supplementary tests were made. As a check on the results of 1931, several hundred single-plant seed selections were made and the progenies tested on the Fairfield plots in 1932. Of these, only four selections from one strain proved to be susceptible, and they were probably the result of accidental escape from infection the previous year.

In 1931 and 1933 pure-line wilt-susceptible Perfection was used as the susceptible check, and in 1932 a pure line of Canners Champion. For the 3 years pure lines of Green Admiral, Bruce, and Stratagem were used successively as resistant checks. In no case did any of the resistant checks wilt.

## EXPERIMENTAL RESULTS

Since Wade (*13*) has shown that peas tested for resistance fall into two discontinuous classes, one entirely susceptible, the other apparently immune to *Fusarium orthoceras* var. *pisi*, it was necessary to establish only two categories for classification of the plants throughout the 3 years' study. In many cases plants selected for resistance and desirable horticultural characteristics were increased during one or two generations on infested soil. In no case was even a single plant lost by wilting, except those noted previously in this circular, and in no case was there an expression of any intermediate reaction to wilt. Many strains of peas contain more than one biotype, some of which may be resistant and others susceptible, but when selections were made from the resistant biotypes they were always found to be resistant in the next generation.

Certain of the homozygous resistant lines selected during the course of this work have been utilized in developing new disease-resistant varieties.

The Shoemaker collection was developed over a period of several years, but in only a few cases was there more than one strain of a variety name. Table 1 shows the frequency distribution with reference to percentage of wilt development of the 477 samples from this collection, grouped according to country of origin. Since Shoemaker found it necessary to increase his strains in close proximity to each other every few years it may be that they became mixed in some instances and consequently did not constitute varieties. However, the records show that many varieties contained more than one biotype when received. A glance at the frequency distribution of peas classified under Alaska, Advancer, and Perfection and not in the Shoemaker collection (table 2) will show that more than one biotype within a variety, as measured by wilt reaction, is common even in strains of canning peas produced in the United States where uniformity is very much stressed by both seedsmen and canners. On the whole it is believed that there is no valid objection to considering the samples in the Shoemaker collection as varieties.

Of the 477 samples in the Shoemaker collection, 297 (62.3 percent) showed no trace of wilt and only 10 (2.1 percent) were completely susceptible. The other 35.6 percent showed more than one biotype with respect to the gene for resistance to fusarium wilt. If the 170 varieties with more than one biotype are arbitrarily divided into two groups—wilting 50 percent or less, and 51 percent or more—and if those 103 varieties that wilted 50 percent or less are added to the apparently immune class and the other 67 to the susceptible class, then 83.9 percent would be classed as resistant and 16.1 percent as susceptible. In other words, in this world-wide collection of peas, the gene for resistance to fusarium wilt is about five times as common as the gene for susceptibility.

TABLE 1.—*Reaction of pea stocks of the Shoemaker collection to fusarium wilt, 1931*

| Country of origin | Number of progenies in their respective percentage classes that developed wilt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 percent | 1 to 5 percent | 6 to 10 percent | 11 to 20 percent | 21 to 50 percent | 51 to 80 percent | 81 to 90 percent | 91 to 95 percent | 96 to 99+ percent | 100 percent | Total varieties |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| United States | 42 | 4 | 2 | 3 | 6 | 6 | 1 | 0 | 0 | 0 | 64 |
| Australia | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| Canada | 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| China | 7 | 0 | 0 | 1 | 3 | 10 | 0 | 0 | 0 | 0 | 21 |
| Denmark | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| England | 69 | 4 | 4 | 10 | 21 | 12 | 5 | 5 | 0 | 7 | 137 |
| Ethiopia | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| France | 44 | 3 | 1 | 3 | 6 | 4 | 3 | 0 | 0 | 1 | 65 |
| Germany | 24 | 3 | 2 | 4 | 4 | 2 | 2 | 1 | 0 | 1 | 43 |
| Netherlands | 34 | 1 | 0 | 2 | 4 | 6 | 1 | 0 | 0 | 0 | 48 |
| India | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Italy | 8 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 10 |
| Japan | 3 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 5 |
| Manchuria | 4 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 6 |
| Peru | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Union of Soviet Socialist Republics | 32 | 2 | 0 | 0 | 4 | 3 | 0 | 0 | 0 | 1 | 42 |
| Venezuela | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Unknown | 11 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 14 |
| Total | 297 | 18 | 11 | 25 | 49 | 47 | 14 | 6 | 0 | 10 | 477 |

The 12 progenies from Ethiopia, Denmark, Venezuela, and Peru, 80 percent of those from Italy, and 85.7 percent of those from Canada (table 1) were immune from wilt. The samples from England, on the other hand, were generally most susceptible, as shown by the low percentage of wilt-immune varieties (50.4) and the highest percentage (5.1) in the 100-percent wilted group, while 61 samples, or 44.5 percent, in those groups with more than one biotype were recorded. Germany ranked next above England in apparently immune progenies with 55.8 percent, followed in ascending order by the United States, France, the Netherlands, and the Union of Soviet Socialist Republics with 65.6, 67.7, 70.8, and 76.2 percent, respectively. The single sample from India was 5 percent susceptible.

The most interesting lot of material was from Ethiopia. While only five stocks or samples were studied, they were composed of a total of at least 50 easily distinguished biotypes, which were given further wilt tests in 1932. Although peas may have originated in Ethiopia, it is understood that they do not now constitute a major crop there, so that 5 progenies from that country may represent as fair a sample as 137 from England. On the other hand the country is difficult to explore and the sampling may not reveal the true condition of Ethiopian peas with reference to reaction to fusarium wilt.

Apparently, resistance is not correlated with either seed size or color, since some of the varieties having very large seeds, as for instance Progress and Giant Stride, are susceptible and resistant, respectively. Varieties with small, colored seeds may be either resistant or susceptible—Austrian Winter stocks are usually mixtures with susceptible biotypes predominating, but those of Bangalia are usually resistant. Varieties with large, colored seeds show a similar diversity—Maple stocks are susceptible and those of Capucijner are usually resistant.

## WILT REACTION OF VARIETIES THAT ARE IMPORTANT OR ARE RELATED TO IMPORTANT VARIETIES IN THE UNITED STATES

The results for all varieties of the 3 years' field tests of wilt resistance and of the supplementary greenhouse test are given in table 2. The Shoemaker varieties tested in 1931 are given without an added letter, but other progenies tested in 1931 are followed by the letter "a"; 1932 and 1933 field tests and the greenhouse test are indicated by b, c, and d, respectively. This table is presented in the form of a frequency distribution with 10 classes, the first with no wilt and the last with 100 percent wilt.

In the following paragraphs the relationships of some of the more important varieties to fusarium wilt are described, and possible explanation of some of the observed wilt reactions is suggested.

TABLE 2.—*Reaction of pea varieties to wilt when grown in soil infested with Fusarium orthoceras var. pisi*

| Variety [1] | Number of progenies in their respective percentage classes that developed wilt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 percent | 1 to 5 percent | 6 to 10 percent | 11 to 20 percent | 21 to 50 percent | 51 to 80 percent | 81 to 90 percent | 91 to 95 percent | 96 to 99 percent | 100 percent | Total progenies |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| Abundance, Improved | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Abundant | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Acacia | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Admiral Beatty | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Admiral Dewey | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Admiral, Green | 2, 11a, 3c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| Admiral, Short | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2c | 2 |
| Admiral, Yellow (and field) | 1c, 2, 3a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| Advance Guard | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Advancer, Webb | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Advancer | 0 | 0 | 0 | 0 | 0 | 0 | 1a | 0 | 0 | 27a | 28 |
| Allan's Canner | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Alaska (ordinary, double, field) | 1, 3a | 0 | 1a | 1a | 10a | 2, 52a, 1c | 22a, 1 | 22a | 1c | 39a, 3c | 159 |
| Alcross Alaska | 0 | 0 | 0 | 0 | 2a | 3a | 0 | 0 | 0 | 0 | 5 |
| Alaska, Maryland | 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Alaska, Wilt-Resistant | 3c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Alderman | 10b, 1, 2a, 6c | 4b, 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1a | 25 |
| Alpha, Laxton | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Amateur Pride | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Alverga, Amarilla | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ameer (Claudit) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2c | 3 |
| American Champion | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| American Wonder | 0 | 0 | 1 | 0 | 0 | 1c | 0 | 0 | 0 | 2b, 3a | 7 |
| Amsterdamsche Broei Vroege Witte | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Arcadian | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Arthur | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ashford | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3d | 3 |
| Badger | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1d | 1 |
| Banqueter | 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Barnet Hero | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Battleship | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Bell | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Belladonna | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Best of All | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Black-Eyed Susan | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Blue Bantam | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1a | 1 |
| Blue Imperial Field | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Blue Prussian | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Borodin | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1c | 2 |
| Bountiful | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1c | 1 |
| Bouquet | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Britisher | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| British Lion | 2c, 1, 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| British Wonder | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Bruce | 2a, 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Buenissimo d'Ingegnoli | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ca Ca | 1a, 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Canadian, White | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Canada Field, Black Eye | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Canning (from Germany) | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Capitol, Svalof | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Capucijner | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Caracactus | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Censor | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Centenary | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Champion of England | 1, 4c | 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1a | 7 |
| Champion of Scotland | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Chancelot | 1, 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |

[1] Unlettered numbers are from the Shoemaker collection and were grown at Fairfield, Wash., in 1931; a, other than Shoemaker collection, grown in 1931; b, grown in 1932; c, grown in 1933; d, grown in greenhouse at Arlington Experiment Farm, Arlington, Va.

TABLE 2.—*Reaction of pea varieties to wilt when grown in soil infested with Fusarium orthoceras var. pisi*—Continued

| Variety | Number of progenies in their respective percentage classes that developed wilt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 percent | 1 to 5 percent | 6 to 10 percent | 11 to 20 percent | 21 to 50 percent | 51 to 80 percent | 81 to 90 percent | 91 to 95 percent | 96 to 99 percent | 100 percent | Total progenies |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| Chang | 0 | 0 | 0 | 0 | 0 | 1, 1a | 0 | 0 | 0 | 0 | 2 |
| Chancellor Field | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| China Field | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Clamart Field | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Clipper | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Colorado Field | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Commander | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Commonwealth | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Concordia, Svalof | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Connoisseur | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1b | 2 |
| Copenhagen Market | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Councillor | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Crochu Roy des-Gourmands | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Cropper, Charlton | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Cupbearer | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Daisy and/or Dwarf Telephone | 1a, 7b, 2c | 3b | 1c | 0 | 1a, 1b | 0 | 0 | 1c | 0 | 0 | 17 |
| Daniels | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| D'Auvergne | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| De Clamart | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| De Grace White Dwarf | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Delicacy Sutton | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Delicatess | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1c | 1 |
| Delicatess Giant | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Distinction, Daniel | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| D'Hollandia | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Duchess | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Duke of Albany | 1, 2c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Duke of York | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Duplex | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1c | 1 |
| Dwarf Champion | 2c | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 4 |
| Dwarf Defiance | 1, 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Dwarf Prolific | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Dwarf Quite Content | 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Earliest Blue Sutton | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Earliest of All | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 |
| Early Bird | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1, 1b | 3 |
| Early Canner | 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Early Duke, Carter | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Early Eight Weeks | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1a | 0 | 0 | 1 |
| Early Giant | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Early Green May | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Early Morn, Carter | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Early Multiple | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Echo | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Edwin Beckett | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Emperor of the Marrow | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Engelsche doppers groene | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| English Wonder | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ensign | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Epicure | 1b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Erbsen Schnabel | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Eureka, wrinkled | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Eureka, smooth | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Everbearing | 1, 5c | 0 | 1a | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 8 |
| Evergreen, Carter | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Excelsior, Nott | 1a | 0 | 0 | 0 | 0 | 1c | 0 | 0 | 1b | 4c,2a,2b | 11 |
| Excelsior, Sutton | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1b, 2c | 3 |
| Exhibition | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Extra Early | 1 | 0 | 0 | 0 | 1c | 1c | 0 | 0 | 0 | 2c | 5 |
| Farnham field | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Favorite, Clibran | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Favourite Marrowfat | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| First and Best | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1c | 1 |
| First Early | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1c | 1 |
| First of All, Sutton | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| First Prize | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Flamische Riesen Schnabel | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Folger | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

TABLE 2.—*Reaction of pea varieties to wilt when grown in soil infested with Fusarium orthoceras var. pisi*—Continued

| Variety | Number of progenies in their respective percentage classes that developed wilt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 percent | 1 to 5 percent | 6 to 10 percent | 11 to 20 percent | 21 to 50 percent | 51 to 80 percent | 81 to 90 percent | 91 to 95 percent | 96 to 99 percent | 100 percent | Total progenies |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| Fordham Favorite | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| For the Millions | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Franco-British | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Fransosische Schnabel | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| French June | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Furst Bismarck | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Gallatin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1b | 0 | 1 |
| Geant de Saumur | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Gem | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3a, 5c | 8 |
| Gem, Premium | 0 | 0 | 0 | 0 | 1a | 0 | 0 | 0 | 0 | 0 | 1 |
| Gem of the Season | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Gems, McLean | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 |
| Gewöhnliche Kleine | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Giant Stride | 1b, 1, 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Gladstone, Sutton Selected | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Glenville Glory | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Glory of Devon | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Golden Marrow | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Golden Vine | 1, 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Goldfinder | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Gold König | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Gontier o Quarantino | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Gradus | 3a | 0 | 0 | 1b | 2b | 3b | 0 | 0 | 0 | 9b, 5c | 23 |
| Gradus, Improved | 0 | 0 | 0 | 0 | 2c | 0 | 0 | 2a | 0 | 1a | 5 |
| Gradus, New Late | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Gradus, Daniel Selected | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Gradus, Selected | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Green Feast | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Green Giant | 5a, 2c | 0 | 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| Gregory | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Groeste groene lente | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Groote Kaapsche groene | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Gros vert a fourrage | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Grunbleibende Konserven Schnabel | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Hamburger Market | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Harbinger, Sutton | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Hardy Norseman, Ryder | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Harrison Glory | 3, 2c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Harvestman | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Heroine | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ho Laan Tau | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Home Delight | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Hooge Groene late | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Horal | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Horsford | 0 | 0 | 0 | 0 | 0 | 1a | 2a, 1c | 1a | 0 | 7a, 5c | 17 |
| Huang Wan | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Hundredfold (Sutton) | 1 | 0 | 0 | 0 | 0 | 0 | 1a | 0 | 0 | 3a, 11b, 5c | 21 |
| Ideal | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 |
| Imperatore (Del) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Imperial, Dwarf Blue | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Imperiale | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Imperial nain vert | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Incomparable | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| International | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Invincible Marrowfat | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Irkutsk Field | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| James Kelway | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Japanese Wrinkled | 1b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| John Bull | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| John Howard | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Juno | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Kabila | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| King Edward | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

TABLE 2.—*Reaction of pea varieties to wilt when grown in soil infested with Fusarium orthoceras var. pisi*—Continued

| Variety | Number of progenies in their respective percentage classes that developed wilt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 percent | 1 to 5 percent | 6 to 10 percent | 11 to 20 percent | 21 to 50 percent | 51 to 80 percent | 81 to 90 percent | 91 to 95 percent | 96 to 99 percent | 100 percent | Total progenies |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| Kneifelerbsen Buxbaum | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Koenigsburg Prince | 0 | 0 | 0 | 1c | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Kootenay | 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Krombek beste opvolgers | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Krombek groote slier | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Krombek Vlijmsche | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Krombek Vroege groene | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Kroonerwten groote groene | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Lancashire Lad | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Langport | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Latest of All, Sutton | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Laxtonian | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1a | 1b | 4c, 6a, 6b | 18 |
| Lentepeul allervroegste | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Leveque | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Leveque nain | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Leveque gros grain blanc | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Liberty, Sharpe | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Lincoln | 1c | 1c | 0 | 1 | 1a | 0 | 0 | 0 | 0 | 0 | 4 |
| Little Marvel | 0 | 0 | 0 | 0 | 0 | 0 | 1a | 1a | 0 | 6c | 8 |
| Little Marvel (smooth) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| London Wonder | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Lord Chancellor | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Lord Leicester | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Maincrop | 3 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| Majestic | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Mansholt | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Manchurian White | 0 | 0 | 0 | 0 | 0 | 3a | 5a | 3a | 0 | 23a | 34 |
| Market, Carter | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1b | 1 |
| Market, Early Improved | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Market Gardener | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Market Surprise | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1a | 3 |
| Marrow, Early Green Seeded | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Marrow, Midsummer | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Marrow, Very Dwarf White | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Marrowfat, Black Eye | 2c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Marrowfat, White Eye | 0 | 0 | 0 | 0 | 1c | 1c | 0 | 0 | 0 | 0 | 2 |
| Marktschatz, Cooper | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Marquis (The) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Masterpiece | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Matchless | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Matchless Marrow | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Mayor of Leicester | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| May Queen | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Meridian, Clucas | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Merveille d'Etampes | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Michaux ordinaire | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Michaux de Ruelle | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Mooie lange Krombek | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Morse No. 200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1b | 1 |
| Multiplier | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Muter field | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Nain hatif ameliore | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Nain hatif a la Reine | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ne Plus Ultra | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| New Deal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1c | 1 |
| New Glory, Johnson | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Nineteenth Century | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Nippon Saya | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Nonpareil, Fairbeard | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Northumbria, Finney | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Old England | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

TABLE 2.—*Reaction of pea varieties to wilt when grown in soil infested with Fusarium orthoceras var. pisi*—Continued

| Variety | Number of progenies in their respective percentage classes that developed wilt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 percent | 1 to 5 percent | 6 to 10 percent | 11 to 20 percent | 21 to 50 percent | 51 to 80 percent | 81 to 90 percent | 91 to 95 percent | 96 to 99 percent | 100 percent | Total progenies |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| Omega | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Onward | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1a, 3c | 4 |
| Ormskirkian | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Overvloeds sterkgewas | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Paragon | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Peacemaker | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Pedigreed Green | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Perfection | 0 | 0 | 0 | 0 | 2a | 12a, 1c | 11a, 1c | 7a | 1a | 83a, 5c | 123 |
| Perfection, Wisconsin Wilt Resistant | 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Perfection, Ormskirk | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Perfection, Sutton | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1b | 2 |
| Perfection, Veitch | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Perpetual | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Peter Pan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2c | 2 |
| Peulen Keiser | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Peulen de Grace | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Peulen Overvloed | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Phenomenon (Sutton) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Phenomenon | 1b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Pigeon (not *Cajanus*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1c | 1 |
| Pilot | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3a, 2c | 5 |
| Pioneer | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1a | 2 |
| Pissarev's No. 317 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Pissarev's No. 318 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Potlatch | 1, 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Poulwell, Brown | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Precoce Romanesco | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| President, Sharpe | 3a | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Prestige | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Pride of the Market | 2c, 1b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Primavera | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Primo | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Prince Albert | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Prince Edward | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Prince of Wales | 1b, 1c | 1, 1a | 0 | 0 | 1c | 0 | 0 | 0 | 0 | 0 | 5 |
| Princessa | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Prior | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Prizewinner | 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Profusion | 1, 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Progress Laxton | 0 | 0 | 0 | 0 | 0 | 2a | 0 | 0 | 1b | 11b, 4c, 3a | 21 |
| Prolifique | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Quarante-deux de Sarcelles | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Quarante-deux vert | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Radio, Charlton | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Rapide | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Rasper ruige groene | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Record | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Rekord | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Recorder | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Regina | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Renown, Sharp | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 |
| Rentpayer | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Rice No. 13 | 0 | 0 | 0 | 0 | 0 | 1, 1a | 0 | 0 | 0 | 2c | 4 |
| Rice No. 330 | 1c | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Ride nain vert hatif | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ride nain blanc hatif | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ridder, witte extra gerimpelde | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ridder, Vroege groen, gerimpelde | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Riesen Schnabel | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Rogers K | 2a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Rogers No. 96 | 1a, 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Roi des Moelles | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Roshia Wase | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ruhm von Cassel | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ruhm von Dietz | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

TABLE 2.—*Reaction of pea varieties to wilt when grown in soil infested with Fusarium orthoceras var. pisi*—Continued

| Variety | Number of progenies in their respective percentage classes that developed wilt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 percent | 1 to 5 percent | 6 to 10 percent | 11 to 20 percent | 21 to 50 percent | 51 to 80 percent | 81 to 90 percent | 91 to 95 percent | 96 to 99 percent | 100 percent | Total progenies |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| Ruhm von Quedlinburg | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Ruhm von Vietz | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Ruhm von Weiss | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| Russian Canning | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sabre | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sapporo Aotenashi | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Samur Ideal | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Saxa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Schnabel Schalerbsen | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Schnabel oder Sabel verbeste | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Schnabel regente | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Scimitar Giant White | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Scotch Beauty | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Scotsman (The) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Senator | 1a, 2c | 0 | 1c | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Serpette ameliore a longue cosse | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Serpette ameliore | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Serpette, cent pour un | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Serpette nain blanc | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Serpette d'Auvergne | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| Serpette de Vitry | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Serpette vert | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Sherwood (The) | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Shropshire Hero | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Smiley | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Snedinge Aerter Danske | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| South China Whites | 3a | 0 | 0 | 0 | 2a | 2a | 0 | 6a | 0 | 5a | 18 |
| South China Colored Japanese | 0 | 0 | 0 | 0 | 1a | 0 | 0 | 0 | 0 | 0 | 1 |
| Standard | 1, 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Stourbridge Marrow | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Stratagem | 1a, 1b, 7c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| Stratagem, Danby | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Sucre, Ride de Knight | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sucre, a rames Ride de Knight | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Sucre, nain Ride de Knight | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Sucre, a rames Ride de Knight vert | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sucre, Sans parchemin hatif | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sucre, Sans parchemin Breton | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sucre, Sans parchemin St. Desirat | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sucre, Mangetout nain ameliore | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sucre, Mangetout Beurre | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sucre, Sans parchemin de quarante jours | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sucre, Mangetout ou Sans parchemin Beurre | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sucre, nain Mangetout | 1c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Dwarf White | 1, 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Sugar, Half Dwarf White | 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Flanders Early Green | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Dwarf Gray | 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Delicate Earliest | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Marrow, White seeded | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

TABLE 2.—*Reaction of pea varieties to wilt when grown in soil infested with Fusarium orthoceras var. pisi*—Continued

| Variety | Number of progenies in their respective percentage classes that developed wilt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 percent | 1 to 5 percent | 6 to 10 percent | 11 to 20 percent | 21 to 50 percent | 51 to 80 percent | 81 to 90 percent | 91 to 95 percent | 96 to 99 percent | 100 percent | Total progenies |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| Sugar, Giant Butter | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Reuzenboter gekreukte | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Reuzenboter | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Mammoth Melting | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Butirro Gigante | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Improved Marrowfat | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar, Sans parchemin corne de Belier | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Sugar, Debarieux nain Mangetout | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Sugar Grosse weiss schwert | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar Tall Moerheim | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar de Grace Oder Buchsbaum | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar Furst Bismarck | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar Krup Zucker | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar Erfurter allerfruheste | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar Thick-podded Butter | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar Heinrich | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sugar Surpasse tout | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Sunrise | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Superb | 0 | 0 | 0 | 0 | 0 | 0 | 1a | 0 | 0 | 3c, 1, 2a | 7 |
| Supreme | 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Surprise | 0 | 0 | 0 | 0 | 0 | 0 | 1a | 0 | 0 | 7a, 2c | 10 |
| Swedish | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sweet Market | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Telegraph | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Telephone, Dark Pod | 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Telephone Tall | 9b | 2b | 1b | 0 | 0 | 0 | 0 | 0 | 1b | 1b, 1a | 15 |
| Telephone | 2, 3c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Thomas Laxton | 1a | 0 | 1b | 0 | 0 | 0 | 0 | 0 | 2b, 1c | 11b, 9a 5c | 30 |
| Timperley Wonder | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Tom Thumb | 2c | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Tres hatif d'Annoy | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Tres nain Couturier | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Trial Ground | 1c, 1a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Trierer Kristallglas | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Triumph | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Triumphant | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Union Jack | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Up to Date | 1b | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Variety unknown, Abyssinia | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Variety unknown, America | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Variety unknown, Hungary | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 |
| Variety unknown, Central Europe | 0 | 6b | 0 | 1b | 1b | 0 | 0 | 0 | 0 | 3b | 11 |
| Variety unknown, Canada | 4 | 0 | 0 | 0 | 2 | 9 | 0 | 0 | 0 | 0 | 15 |
| Variety unknown, Manchuria | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Variety unknown, Soviet Union | 28 | 2 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 1 | 37 |
| Variety unknown, Venezuela | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Variety unknown | 7 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1c, 21 | 31 |
| Vert commun du Nord | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vert des Champs Tries | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vert des Champs | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| Victor | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |

TABLE 2.—*Reaction of pea varieties to wilt when grown in soil infested with Fusarium orthoceras var. pisi*—Continued

| Variety | Number of progenies in their respective percentage classes that developed wilt | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 percent | 1 to 5 percent | 6 to 10 percent | 11 to 20 percent | 21 to 50 percent | 51 to 80 percent | 81 to 90 percent | 91 to 95 percent | 96 to 99 percent | 100 percent | Total progenies |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| Victor, Charlton | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Victoria | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| V. C. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| V. I. S. No. 2360 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Vorbote or Eclipse | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vroege Bismarck | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vroege Groene | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vroege halfstamde of Eenling | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vroege stam Kruip | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vroege Veertigdaagsche | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Warriston Wonder | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Wellington | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Western Express | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| White Canning, Hurst | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| William Hurst | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| William Richardson | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Winner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1c, 1a | 2 |
| Wonder Marrowfat | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Wonder of Witham | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Worlds Prize | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| World Record | 0 | 1b, 1c | 0 | 2b, 1c | 4a, 4b | 1a, 3b | 0 | 0 | 0 | 1c, 2a, 1b | 21 |
| Yorkshire Hero | 2, 3a | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Total | | | | | | | | | | | 1,334 |

**Admiral (Green, Yellow, and Short), and Rogers K.**—It is of interest to note that all strains of Green Admiral and Yellow Admiral are wilt-resistant and that Short Admiral, selected from a cross of Green Admiral with a wilt-susceptible variety, is completely wilt-susceptible. This is especially interesting when it is known that this variety was bred in Wisconsin at a time when at least some of the susceptible types were being eliminated by fusarium wilt. Rogers K is a few days earlier than Green Admiral but is otherwise essentially the same.

**Advancer, Abundance, and Perfection.**—Perfection is the most common of the wrinkled canning peas and is similar to and probably derived from Advancer. Some seed companies sell seed under both names but from only one stock; in New York it is sold as Advancer but in Wisconsin as Perfection. Abundance, Improved Abundance, or Bliss Abundance is more variable than Perfection, but it can usually be differentiated from the other two varieties by the slightly shorter, stockier vine, by smaller pods enclosing the peas more tightly than Perfection or Advancer, and by the fact that most strains are slightly earlier, blooming at the thirteenth node instead of at the fourteenth as in the case of Perfection and Advancer. Although Abundance is a good canning variety and cannot be distinguished from Perfection in the can, it does not appear quite so well in the field, but under adverse conditions it seems to stand up better than

Perfection. Hedrick et al. (*4*) consider Perfection to be a selection from Abundance, but it seems to be more closely related to Advancer both in appearance and reaction to wilt.

Most strains of Abundance are wilt-resistant, but susceptible strains do occur. Of 28 strains of Advancer tested in 1931, 27 were completely susceptible; out of a total of 123 strains of Perfection tested over a period of 3 years, 88 were completely susceptible. Only one strain of Abundance was tested in these trials, and it proved to be completely resistant. Many of the survivors found in Perfection were tested for susceptibility to wilt the following year and all were found to be resistant, but none proved to be typical Perfection plants. Abundance was the most common offtype found in Perfection, although Green Admiral, Alaska, Green Giant, and other varieties were present. It is interesting to note that Walker (*14*) found a much smaller percentage of survivors, 0.2 percent, in the Perfection strains tested for wilt resistance in 1930.

In the future wilt-susceptible Perfection strains may be difficult to obtain, because several completely wilt-resistant strains are now available and are desired for the canning crop in some areas where fusarium wilt is serious. Only by the closest examination can these strains be distinguished from wilt-susceptible Perfection in the field, and it is impossible to distinguish them in the can.

**Alaska.**—Alaska is a relatively uniform variety, usually blooming at the eighth node. Much variation in node of bloom is usually understood by the competent seedsman to mean that the stock in question is not a canning stock but a field seed stock. There is normally some variation in bluntness of pod. Of 159 strains of Alaska tested, 42 were completely wilt-susceptible, 4 were completely resistant, and 113 strains contained both resistant and susceptible biotypes. Alcross Alaska was represented by five progenies; they showed from 46 to 80 percent wilting. Three strains acquired as wilt-resistant Alaska were found to be completely resistant.

Practically all the wilt-resistant Alaskas have been developed by selection in contrast to the intensive breeding work necessary to produce the resistant Perfections. In general, strains of Alaska tested are predominantly wilt-susceptible.

**Alderman.**—Alderman is a tall, medium-late variety usually grown on trellises and most commonly found in commercial fields in the Puget Sound section of Washington and in some parts of California. It is widely grown in home gardens. There has been some occasion to confuse Telephone and Alderman, but during the last few years the light foliage types, characteristic of the Telephone, have almost disappeared from the market. In some areas, notably the Puget Sound in Washington, some satisfactory substitution of the English exhibition types has been made from Alderman, especially Quite Content and V. C. Twenty-five strains under the name of Alderman were tested, of which 19 were completely resistant, 5 were placed in the 1- to 5-percent susceptible class, and 1 was completely susceptible. From the habit of growth of this last susceptible strain it could not have been true Alderman.

**Ameer.**—Ameer or Claudit is a large-podded Alaska type used somewhat by market gardeners. It occurs typically in both wilt-resistant and wilt-susceptible forms.

**American Wonder.**—American Wonder is essentially a susceptible variety. The resistant biotypes in two of seven progenies in table 2 were not characteristic of the variety.

**Capucijner Group.**—Capucijner peas are imported into the United States from the Netherlands for food purposes. This group contains several varieties, most of which are completely wilt-resistant; a few, however, are almost completely susceptible. Table 2 lists four as completely resistant.

**Daisy.**—Daisy and/or Dwarf Telephone typically is resistant, but many stocks with a small percentage of susceptible biotypes are still found. Of the 17 stocks examined, 10 were completely resistant, 6 contained from 1 to 50 percent susceptible plants, and 1 which was distinctly not of the varietal type was over 90 percent susceptible.

**Dwarf Early Market-Garden Types.**—This group with zigzag stems includes Hundredfold (Sutton), Laxton Progress, Peter Pan, Pioneer, Laxtonian, Blue Bantam, Little Marvel, Nott Excelsior, Sutton Excelsior, American Wonder, and others, all of which are typically wilt-susceptible. In this group not a single wilt-resistant survivor was found that approached the types of these varieties or that had any economic promise.

**Laxton Progress.**—Laxton Progress was introduced to the seed trade in 1922 and is undoubtedly the most important early market-garden pea in the United States. Over half of California's annual planting of 60,000 to 70,000 acres is devoted to this variety. Most seedsmen do not list any improved or variant strains of this variety, and since it has relatively larger pods than any of the other dwarf, early wrinkled varieties, substitutions for it are not attempted. In 1931 five strains were grown, three of which wilted completely and two partially (one between 71 and 75 percent and the other, 76 and 80 percent). The progenies of four surviving plants were completely eliminated in the next test, and the survivors from the other progeny were definitely not Laxton Progress. In 1932, 12 strains were grown, of which all of the plants of 11 wilted, and in the twelfth there was only 1 survivor, a tall, rogue plant. All of the plants of the four strains grown in 1933 were killed completely. Because of its apparent complete susceptibility, Laxton Progress might be considered as an additional susceptible check carried through the 3 years.

**Hundredfold.**—Hundredfold (Sutton) is next in importance to Laxton Progress. Many seed companies fill orders for Laxtonian with Laxton Progress or with Hundredfold, and many of the so-called dark-podded strains of Laxtonian are merely unimproved strains of Hundredfold. Of 21 strains of Hundredfold grown, 19 were completely susceptible, 1 was 86 to 90 percent susceptible, and 1 was completely resistant. The last-mentioned strain has a straight stem and smooth yellow seeds, quite evidently neither the Carter nor the Sutton strains of Hundredfold, and considering the small size of the pods, it could not be regarded as a market-garden type. The biotypes in this strain that did not wilt completely were certainly not Hundredfold (Sutton).

**Field Peas, Canada and Colorado.**—Canada Field peas are usually wilt-resistant regardless of the name under which received.

Colorado Field peas are usually a mixture of Canada Field, First and Best, Extra Early, Bangalia, and other varieties so that the one

progeny in the 21- to 50-percent class probably represents a fair average for wilt reaction.

**Green Giant.**—Green Giant is a strain of Prince of Wales in which the vine type approaches Perfection. Like Prince of Wales it is typically wilt-resistant.

**Giant Stride.**—Giant Stride was found to be typically wilt-resistant. This variety has been observed under many synonyms. All strains tested are wilt-resistant.

**Gradus.**—Twenty-three strains of Gradus were tested, of which 14 were completely susceptible, 3 resistant, and 6 a mixture of biotypes. The resistant types for the most part were too small podded for typical Gradus. Improved Gradus is later than Gradus and the type is not well fixed. New Late Gradus was more like Stratagem and Selected Gradus appeared to resemble World Record more than Gradus.

**Horal.**—Horal is completely resistant to fusarium wilt, but there is no evidence to indicate that it is tolerant or resistant to root rots as has been stated in some publications.

**Japanese Wrinkled.**—Japanese Wrinkled (or dimpled) peas usually resemble Harrison Glory rather closely. Only one is listed here, but many others have been observed to be resistant.

**Marrow type.**—In the United States, marrow or marrowfat refers to a large white or yellow type of field pea. In England the term has a wider application, including many wrinkled varieties used in market gardens. In order to avoid confusion these peas were not grouped under marrows or marrowfats except where it seemed clear that the United States usage would apply. Most of the marrow varieties are wilt-resistant.

**Morse No. 200.**—Morse No. 200 resembles Duplex in type. Both are completely susceptible to fusarium wilt, but Morse Market (not listed in table 2) has been observed elsewhere to be completely resistant.

**Onward.**—Four strains of Onward were found to be completely susceptible.

**Phenomenon.**—Phenomenon (Sutton) from England seems to be highly susceptible to fusarium wilt (91 to 95 percent), but an American strain of apparently the same variety (listed in table 2 as Phenomenon) was completely resistant.

**Pigeon.**—Pigeon is a commercial sample of common pea probably imported for pigeon feed. It is not *Cajanus indicus* Spreng. This sample was recorded as completely susceptible.

**Profusion.**—Profusion is a competitor of Prince of Wales, and was found to be wilt-resistant.

**Senator.**—Senator is a wilt-resistant variety and the susceptible biotypes found therein are not typical. In the district near San Diego, Calif., Senator is grown under the name of Admiral for market-garden purposes.

**South China and Manchuria.**—South China peas are considerably mixed as to variety. They are quite evidently not native Chinese peas, but imported varieties grown for export. The predominating type is wilt-susceptible First and Best. Peas from Manchuria are more uniformly wilt-susceptible, but on the whole they are fairly close to First and Best in varietal characteristics.

**Stratagem.**—Stratagem (Potlatch) strains are essentially wilt-resistant, but the one strain of Danby Stratagem from England showed 76 to 80 percent susceptible.

**Surprise and Wisconsin Early Sweet.**—Surprise is probably one of the best-quality varieties available for canning at the present time, but its susceptibility to wilt and generally light yields have prevented it from gaining much popularity. During the last few years it has been largely replaced by Wisconsin Early Sweet (not listed in table 2) and other wilt-resistant strains arising from crosses of Surprise with Alaska which possess much of Surprise quality and the yielding ability of Alaska.

**Thomas Laxton.**—Twenty-five of the thirty strains of Thomas Laxton tested were completely susceptible and three were 96 to 99 percent susceptible. The two progenies rated 0 and 6 to 10 percent susceptible were Alderman types and the survivors in the 96- to 99-percent class were not typical of Thomas Laxton.

**World Record.**—World Record strains range in susceptibility to fusarium wilt from 1 to 100 percent, although most of the progenies vary from 1 to 55 percent susceptible. No completely susceptible strain is shown in table 2, but many have been observed under field conditions.

## DISCUSSION

### RELATION OF CLIMATE TO THE PREVALENCE OF PEA WILT

Two areas in the United States in which fusarium wilt of peas has caused the most extensive damage, southern Wisconsin and eastern Washington, have very similar curves for mean monthly maximum and mean monthly minimum air temperatures, as is shown in figure 2. The southern Wisconsin rainfall is about 35 inches annually and the eastern Washington about 20. Usually very little rain falls in the latter area during the pea-growing season (May to September), but in Wisconsin rains occur frequently during the growing season. At San Luis Obispo, Calif., a small acreage of peas is damaged annually by fusarium wilt, but the spread there has been very slow as compared with that in Wisconsin or Washington. The temperature curves for Addis Ababa, Ethiopia, at an elevation of 8,005 feet (near where peas are believed by some to have originated), are very similar to those for San Luis Obispo. Curves for Berlin, Rotterdam, and Greenwich are intermediate between those for San Luis Obispo, Calif., and Madison, Wis. The relatively dry climates of Kerman, Persia, and Leningrad and Shusha, Union of Soviet Socialist Republics, show great ranges between mean maxima and mean minima. At the present time large acreages of peas are grown in the northern part of the Soviet Union, but no wilt has been reported. Shusha and Kerman are probably fairly typical of southeastern Europe and of the mountain regions of Persia, respectively. A comparison of the various curves in figure 2 indicate that if *Fusarium orthoceras* var. *pisi* should be introduced into Eurasia or Africa for the most part it would not have to survive greater temperature variations than it does in the United States.

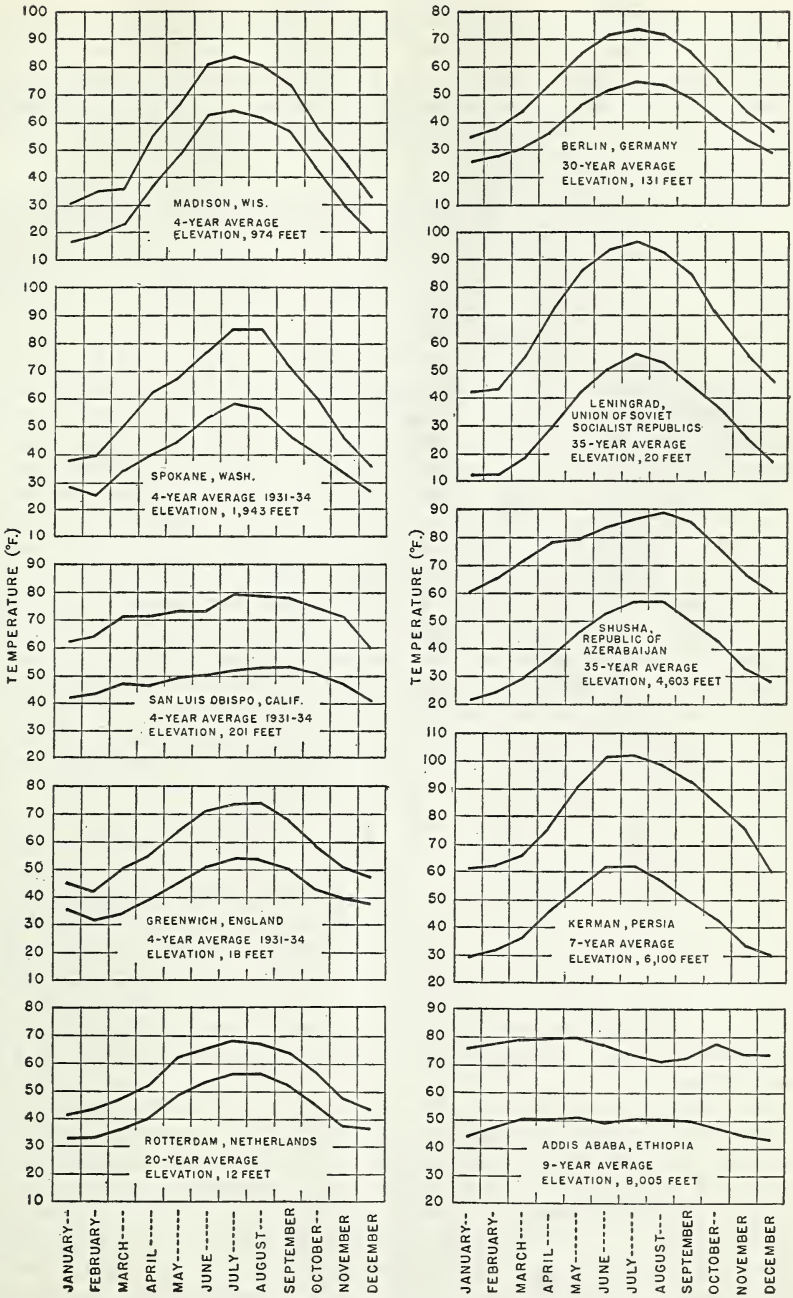


FIGURE 2.—Mean monthly maximum and minimum temperatures in or near various pea-growing areas of the United States, Eurasia, and Africa.

## ORIGIN OF PEA VARIETIES IN RELATION TO WILT

Vavilov (*12*) states:

> The centers of origin of a certain group of cultivated plants are generally characterized by many specialized parasites peculiar to a given group of plants. Thus the center, where the diversity of specialized parasites characteristic of a certain group of plants is concentrated, coincides, as might have been expected, with the center of their hosts.

The present unequal distribution of pathological work makes it impossible to apply this principle with any degree of accuracy in the case of the pea. Insofar as present information goes the greatest diversity of pea diseases exists in the United States and northern Europe. Fusarium diseases are especially prevalent in the United States, and some have been reported from Europe.

On the basis of the present knowledge of the distribution of fusarium diseases of peas and according to Vavilov's general theory of diversity of pathogens, Ethiopia should be a rich field for the investigation of wilt resistance and of variations in the causal organism, but there is no evidence that the organism occurs there.

How susceptibility to pea wilt originated can be only a matter of speculation. If it is assumed that the disease did not affect the wild pea types in their native environment then the origin must be sought elsewhere. Several hypotheses might be offered.

(1) The domestic cultivated pea may have descended from crosses involving susceptible forms, such as some field-pea types with which the garden pea hybridizes. The Austrian Winter pea is said to exist in its native state in the southern part of the Union of Soviet Socialist Republics and for the most part is susceptible to wilt. If hybridized with a resistant, large-seeded type from the Mediterranean the gene for susceptibility might have been transmitted to the garden pea. Following introduction of such peas into districts, such as are to be found in the United States, where the wilt parasite exists and climatic conditions are favorable for its development, the disease might appear in an epidemic form.

(2) If wilt-susceptible *Pisum elatius* Stev. is the wild progenitor of *P. sativum*, as Scheibe (*7*) believes, then the gene for susceptibility is probably older than the gene for resistance. However, if such is the case there must be in nature some difference in survival values in favor of wilt-resistant biotypes (even where the disease does not occur) to account for resistance being much more common than susceptibility, since in recent tests *P. elatius* has been found to be wilt-susceptible.

(3) A third hypothesis might be advanced. The progenitor of the garden pea is no longer found in the wild state. Garden peas have been in cultivation for many years and have gone through many stages of improvement by hybridization, cultivation, and domestication, so that the present product is probably very different from the primitive stock. During the many years changes have probably taken place. It is of course possible that a mutation of the gene for resistance, *Fu* (Wade, *13*), to the gene for susceptibility, *fu*, has occurred more than once, so that wilt-susceptible varieties are not necessarily derived from the same source. However, with the extensive crossing work carried on in England and later in the United States,

it seems probable that many of the garden and canning varieties are very closely related. Histories of some of the varieties and the appearance of others would tend to indicate a close relationship of a number of them.

So far as is known the pea wilt disease does not occur in England, which may be because the causal organism is not present there or because the climatic and other conditions are not favorable for its development. One might argue that only resistant varieties are grown there, but as a matter of fact, the data contained in table 2 show that susceptible varieties are grown in England, and also in Germany, and some other foreign countries. The prevalence of the disease in the United States only, therefore, must be accounted for by the fact that the causal organism exists in great abundance in certain regions. So far as is known, the disease causes no damage in certain other regions. This may be because the causal organism has not been introduced rather than that climatic conditions are unfavorable for it. In view of the fact that the organism is seed-borne in almost negligible amounts, such regions may remain free for a long period of time. Viewed from any standpoint, no positive proof can be advanced to account for the origin of the fusarium wilt of peas.

The lack of plant-disease surveys in some of the foreign countries makes it impossible to state what diseases of peas may be present. Tests show that all the varieties from some countries are immune to wilt. Whether they are immune because of the elimination of the susceptible varieties and the survival of the resistant, or whether it is a mere matter of chance cannot be definitely stated. In this connection it is well to remember that the largest percentages of susceptible varieties come from those countries where the most work has been and is being done in the breeding and production of new strains, but without reference to wilt resistance. All strains tested from Ethiopia, Denmark, Venezuela, and Peru were 100 percent resistant, whereas those from England showed the highest percentage entirely susceptible and the lowest resistant.

The geographical origin of the pea is uncertain. It has never been found in the wild state and where it might have originated can be only a matter of speculation. Vavilov (*12*) believes that the original races of peas came from Ethiopia, small-seeded ones from southwestern Asia, and large-seeded ones from the Mediterranean region. Shoemaker and Delwiche (*8*) state that peas have two primary points of origin, Ethiopia and the Persian-Afghanistan mountain region, with a secondary center in Mediterranean Europe. Hedrick et al. (*4*) believe that the pea originated in eastern Europe and western Asia and that it may possibly be a descendant of the field pea, *Pisum sativum* var. *arvense* (L.) Poir., with which it crosses readily.

In this circular field and garden peas are considered to be the same species. No samples directly from Persia or Afghanistan are represented in the collections tested, but it is probable that many of the samples from the Union of Soviet Socialist Republics originated in these countries as perhaps did also the lot from India. Thirty-two of the forty-two progenies from the Soviet Union were completely wilt-resistant, whereas the one from India fell in the 1- to 5-percent-susceptible class.

England is undoubtedly the center of the world's pea breeding and it seems to be there that the gene for resistance is being lost, or at least there is where the greatest number of wilt-susceptible varieties have originated.

The United States holds a rather unique position, for it is a country in which peas are grown on a very extensive scale, and over 90 percent of the production is limited to less than 15 varieties. While 65.6 percent of the varieties collected in the United States fall in the immune class, many of them are of no significance from the standpoint of acreage grown. These facts explain how the United States could have such an acute fusarium wilt problem and still show fairly high rank in resistance when the total number of varieties is considered. However, most of the 64 progenies listed as collected in the United States undoubtedly had their varietal origin in other countries. Over half the acreage for canning peas and two-thirds of that for commercial dry soup peas is planted to one variety, Alaska. Perfection (Advancer) is the next most important canning variety. During years of trouble with root rots Green Admiral comes to be of some significance. These varieties are all of American origin, and the first two are typically wilt-susceptible, but during the past few years wilt-resistant strains have been introduced. Green Admiral is a primitive type differing from Yellow Admiral probably by only one or a few genes. Both Admirals are wilt-resistant. In the market-garden group Laxton Progress, Hundredfold, Thomas Laxton, Alderman, Giant Stride, and Stratagem are the most important. These are of English origin, but some improvement has been made by United States breeders in Hundredfold, Stratagem, and Giant Stride. All strains of Giant Stride and nearly all of Stratagem and Alderman are wilt-resistant, but the three early varieties are completely susceptible.

### RELATION OF PRIMITIVE TYPES TO RESISTANCE

As previously mentioned, there is no evident correlation between resistance and any visible seed characters. This would tend to indicate that both resistant and susceptible forms originated rather early in the history of the pea.

Throughout the observations of 1931–33 it was evident that most strains representing primitive types of peas are resistant to fusarium wilt, that nearly all the early-maturing, highly developed types are wilt-susceptible, but that over half of the later highly developed types are resistant. Of 33 varieties of edible-podded or sugar peas considered in this study none showed as much as 50 percent susceptibility to fusarium wilt. The edible-pod factors could not be considered primitive on account of the low-survival value of edible-podded strains, even when grown with some protection against birds. Most of the edible-podded peas are relatively old varieties and the edible-podded condition is very frequently found in varieties that otherwise appear to be quite primitive.

Practically all American varieties are merely variations of English varieties, or were so until fusarium wilt in this country forced a definite breeding program for wilt resistance. The canning variety Perfection is a slight variation from Advancer, and Alaska is a vari-

ant from Earliest of All. Some strains of Earliest of All are wilt-resistant, but nearly all are a mixture of biotypes (table 2 and Walker (*14*)). Typical Perfection and Advancer are completely susceptible except certain strains bred especially for resistance. Nearly all the resistant biotypes recorded in table 2 for Advancer and Perfection were found to be Abundance with a few approaching Perfection in type but not near enough to be classified as Perfection by critical observers.

Shoemaker and Delwiche (*8*) refer to Yellow Admiral as one of the most primitive types of pea varieties in use at the present time on account of its small pods, leaves and stipules, and its height, season, and habit of growth. Yellow Admiral is considered as identical with Fairbeard Nonpareil, which was introduced in 1853. Many of the canning peas received from Europe are found to be Yellow Admiral. Fairbeard had only a few varieties with which to work, largely ones produced by Knight in England about 1787. It is interesting to note that seven of the eight Knight sugar varieties collected from France were completely resistant to fusarium wilt, and the eighth showed only a trace.

## POSSIBLE ORIGIN AND SURVIVAL OF GENES DETERMINING RESISTANCE AND SUSCEPTIBILITY

In searching for the origin of wilt susceptibility in peas, it is necessary to go back at least to Advancer, which was introduced in 1860. Both Advancer and Alaska have in their ancestry Beck Gem, which may have been wilt-susceptible. Nearly all Gem strains now available are susceptible. It is rather difficult to explain how the factor for susceptibility could have become a part of the genic complex of so many important American varieties, since, under conditions in which wilt does not occur, it would have about the same survival value as the gene for resistance, *Fu;* but where the disease does occur, as in the United States, it would have a negative survival value. The old important varieties were developed where wilt is not known to occur. It is only by assuming some linkage of the gene for susceptibility, *fu*, with some desirable horticultural characteristic that its establishment would appear possible. Some of the most intensive work done by the English pea breeders has been to obtain very early dwarf varieties with large pods. All these dwarf earlies with short internodes and most of the other early varieties, including those with long internodes such as Thomas Laxton, Gradus, and Alaska, are susceptible. Wade (*13*) reported a small amount of linkage of the factor for resistance, *Fu*, with the factor for internode length, *Le*, investigated by White (*15*). If in the earlier stages of the development of pea varieties this linkage value should have been very great then the establishment of wilt-susceptible early strains would have been the highly probable outcome of any breeding work to incorporate the factor for short internode into the strains worked with.

*Fusarium orthoceras* var. *pisi*, the organism causing pea wilt, has been reported only from the continent of North America, but it is quite evident that the gene for resistance did not arise there, but probably in Ethiopia or the Persian-Afghanistan plateau region. The gene for resistance must have arisen relatively early in the his-

tory of the pea plant to have such common occurrence in the pea varieties of the world. A consideration of this possible origin brings up an interesting question: Has *F. orthoceras* var. *pisi* occurred early in the history of peas, killed out all the susceptible types, and in turn been eliminated for lack of a suitable host from Africa and Eurasia? However, since *F. orthoceras* var. *pisi* is able to survive as a saprophyte over a very long period of time, perhaps indefinitely, it does not seem reasonable to suppose that at one time it could have been abundant in other parts of the world and now be extinct there. This would indicate that the gene for resistance to fusarium wilt is very old, perhaps as old as the species itself. It is difficult to believe, however, that most of a species would be equipped with a definite factor for resistance to the attacks of a very specific organism, without that organism ever having been present in the region where the species arose, unless the gene for resistance were more general in its actions. Unpublished results by the authors indicate that resistance to *F. orthoceras* var. *pisi* is not correlated with resistance of the host plants to certain other species of vascular fusaria nor with resistance to cortical invasion by organisms such as *F. martii* App. and Wr. var. *pisi* F. R. Jones. This of course does not deny that the gene for resistance may have some other function not yet discovered.

From Fisher's (*1*) theory of the evolution of dominance—that even dominant genes originate as recessives and gradually become part of the wild type gene complex—we might expect to find cases in crosses where dominance is not quite complete. Crosses between many different types have been made in addition to those originally reported by Wade (*13*), but in no case has anything except complete dominance of *Fu* been found. There is no indication of modifying factors or of more than one gene for resistance or susceptibility.

Not much work in plant pathology has been done in Ethiopia, Persia, or Afghanistan so that it appears reasonable from the foregoing discussion to conclude that it would be worth while to make a diligent search of these countries for *Fusarium orthoceras* var. *pisi*. It is known that the organism may invade the cortex of some of the small rootlets of resistant plants to a slight extent, thereby providing for its survival in a region such as Ethiopia where apparently only resistant varieties are grown. If the wilt organism were originally present in Ethiopia or other centers of origin, since it is seed-borne to some extent, it must have been distributed to many other parts of the world; and although it may have died out in some regions it seems improbable that it would die out throughout Eurasia in every place introduced. If Africa and Eurasia are eventually found to be free from *F. orthoceras* var. *pisi*, then there would be some evidence of a case of negative preadaptation of susceptibility (*2*).

## SUMMARY AND CONCLUSIONS

A total of 1,024 strains of peas were grown on wilt-infested (*Fusarium orthoceras* var. *pisi*) soil near Fairfield, Wash., in 1931 and the reactions were observed. Four hundred and seventy-seven of these were from a world-wide collection by D. N. Shoemaker, and were used to determine the distribution of resistance. It was found

that resistance was approximately five times as common as susceptibility, that susceptible or partially susceptible varieties were more common in England than in other countries, and that no susceptible varieties were obtained from Ethiopia where peas are believed to have had their origin. In 1932 and 1933, 310 additional strains were grown.

It is concluded from the wide distribution of resistance and its occurrence in presumably primitive types and in old varieties dating back as much as 150 years, that the gene for resistance, *Fu*, is probably older than the gene for susceptibility, *fu*. Speculations on the origin and survival of genes for resistance and susceptibility, on distribution, and climatic tolerance of the pathogen, are included.

In addition to the Shoemaker collection, 857 strains of peas were grown, most of which were American strains of garden and canning varieties. Nearly all the important American varieties were found to be susceptible, and the resistant biotypes found in susceptible varieties were usually not typical of the variety in which found, except in the case of Alaska and World Record. Also, susceptible biotypes found in resistant varieties were rarely typical of the variety.

Dwarf early market-garden varieties with short internodes (i. e., zigzag stems) were all found to be completely susceptible, and no resistant rogues of any horticultural value were found.

In the case of some important varieties susceptibility and resistance are discussed, and possible explanation of some of the wilt reactions is suggested.

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